US009410562B2

(12) **United States Patent**
Besemer et al.

(10) **Patent No.: US 9,410,562 B2**
(45) **Date of Patent: Aug. 9, 2016**

(54) **HYDRAULIC POWER SYSTEM**

(71) Applicant: **EATON CORPORATION**, Cleveland, OH (US)

(72) Inventors: **Scott M. Besemer**, Battle Creek, MI (US); **Andrew N. Edler**, Homer, MI (US); **Matthew George Fox**, Ceresco, MI (US)

(73) Assignee: **Eaton Corporation**, Cleveland, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/852,880**

(22) Filed: **Sep. 14, 2015**

(65) **Prior Publication Data**

US 2015/0377260 A1 Dec. 31, 2015

Related U.S. Application Data

(63) Continuation of application No. PCT/US2014/027913, filed on Mar. 14, 2014.

(60) Provisional application No. 61/798,893, filed on Mar. 15, 2013.

(51) **Int. Cl.**
F16D 31/02 (2006.01)
F15B 13/044 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F15B 13/044*** (2013.01); ***B62D 5/07*** (2013.01); ***F15B 1/26*** (2013.01); ***F15B 11/08*** (2013.01); ***F15B 11/162*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC F15B 11/162; F15B 1/26; F15B 13/044; F15B 13/026
See application file for complete search history.

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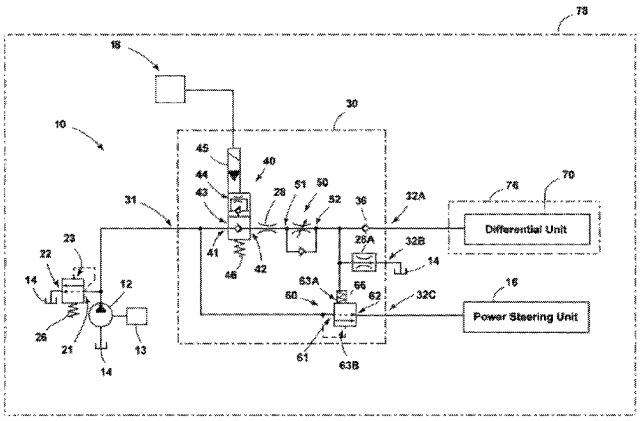
Primary Examiner — Nathaniel Wiehe
Assistant Examiner — Daniel Collins
(74) *Attorney, Agent, or Firm* — Dykema Gossett PLLC

(57) **ABSTRACT**

A hydraulic actuation system includes a differential unit having a hydraulically-actuated differential, a power steering unit, a hydraulic pump, a reservoir, a controller, an electronically-controlled flow control manifold, and a proportional pressure control solenoid valve. A flow control manifold may control fluid flow to the power steering unit and the differential. The manifold may include a manifold inlet connected to a pump; first manifold outlet connected to a differential; second manifold outlet connected to a reservoir; third manifold outlet connected to a power steering unit; two-way solenoid valve connected to a manifold inlet and controlled by a controller; flow control valve connected to a two-way solenoid valve and a first manifold outlet; and a pressure differential sensing valve connected to a two-way solenoid valve, the manifold inlet, and the third manifold outlet. A proportional pressure control solenoid valve may connect the first manifold outlet and the differential.

20 Claims, 5 Drawing Sheets



(51) **Int. Cl.**

B62D 5/07	(2006.01)
F15B 11/16	(2006.01)
F15B 1/26	(2006.01)
F15B 11/08	(2006.01)
F15B 13/02	(2006.01)

(52) **U.S. Cl.**

CPC ***F15B 13/026*** (2013.01); *F15B 2211/212* (2013.01); *F15B 2211/40553* (2013.01); *F15B 2211/50563* (2013.01); *F15B 2211/5158* (2013.01); *F15B 2211/7135* (2013.01); *F15B 2211/781* (2013.01)

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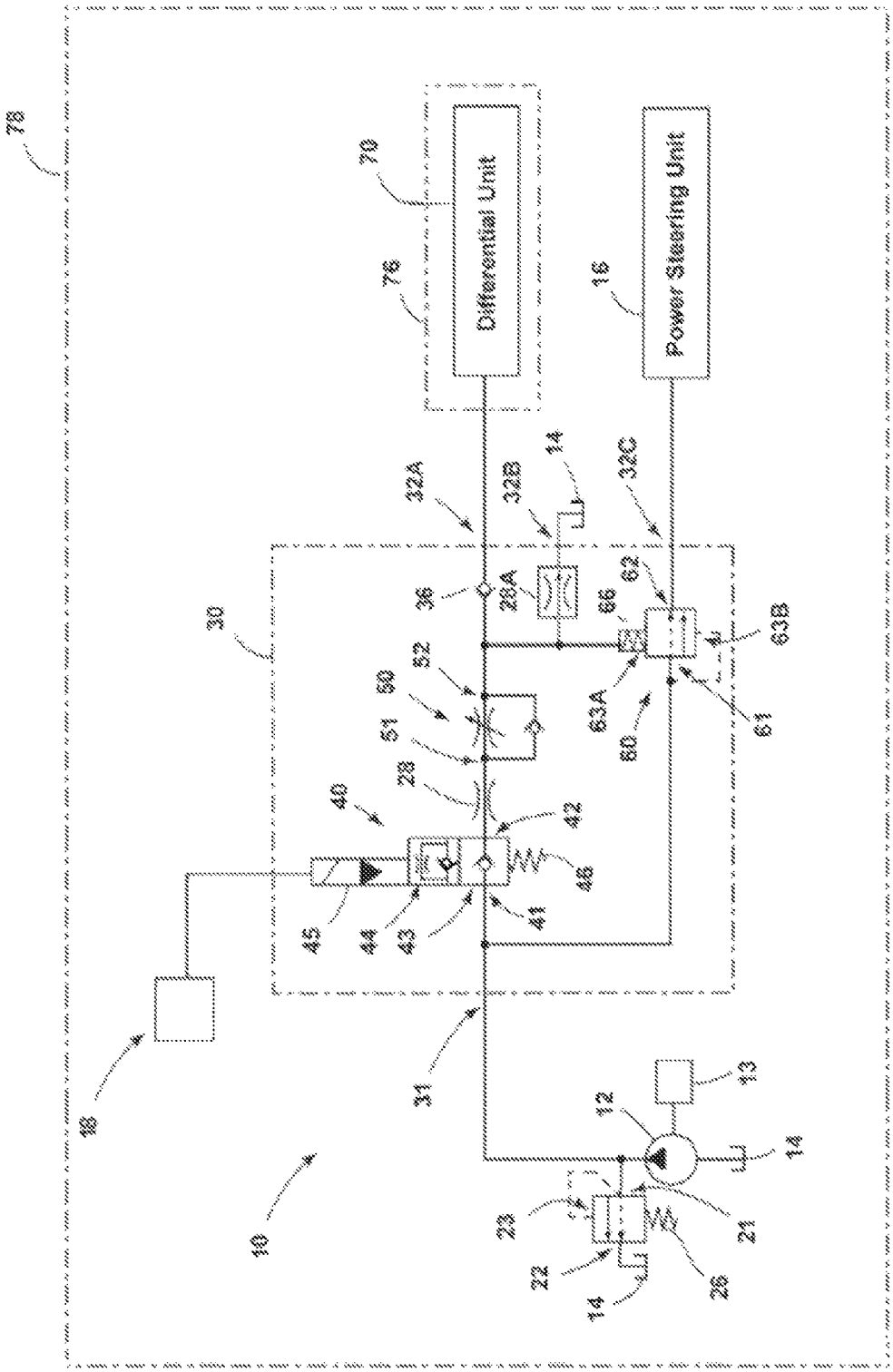
78
70
Differential Unit
76
16
Power Steering Unit
14
32A
32B
32C
36
28A
66
62
63B
63A
60
61
30
52
50
51
28
40
42
46
45
44
43
41
48
31
13
12
14
23
21
22
14
26
10

FIG. 1

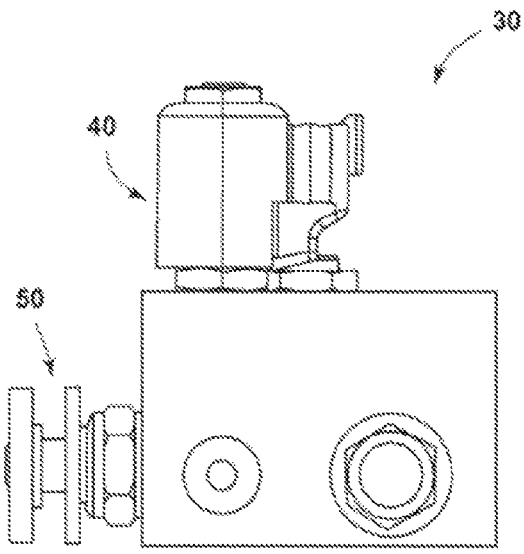

FIG. 2

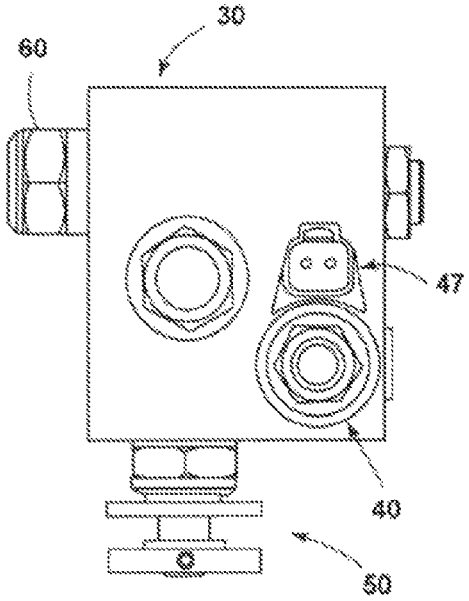

FIG. 3

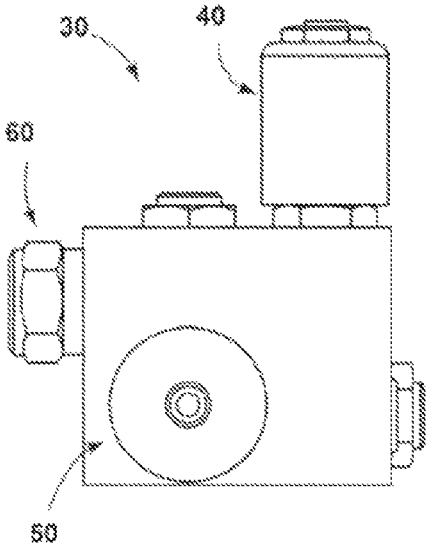

FIG. 4

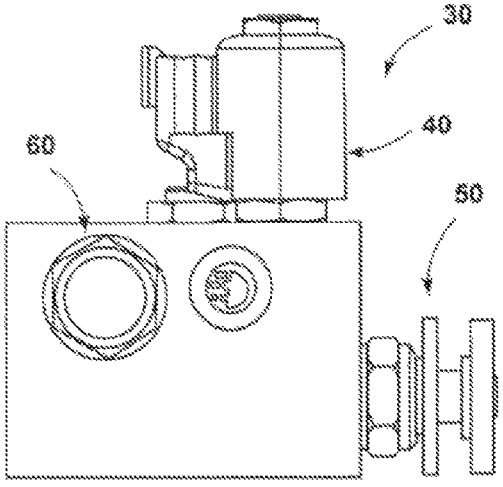

FIG. 5

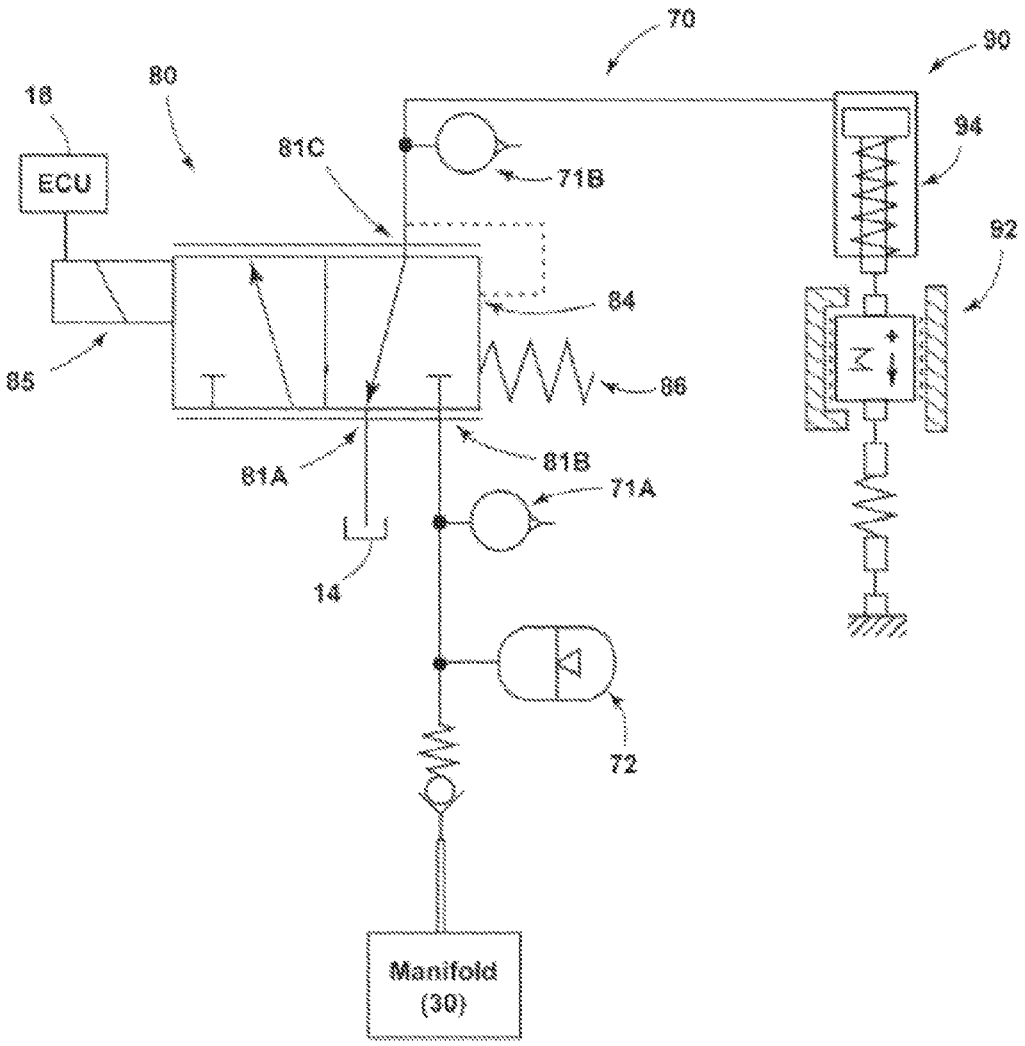
70
90
18
80
ECU
81C
71B
94
92
84
85
86
81A
81B
71A
14
72
Manifold
(30)

FIG. 6

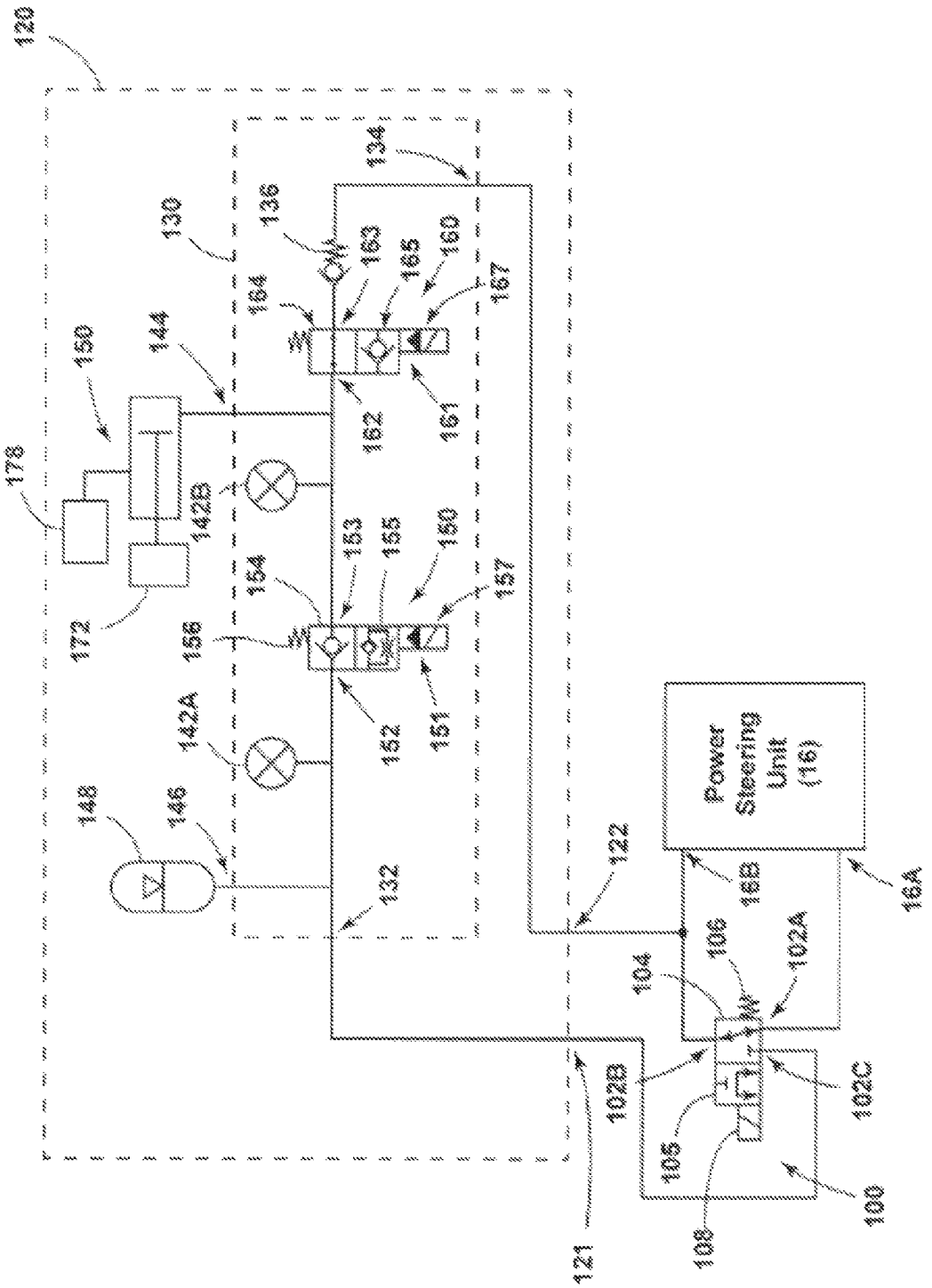
120
134
136
130
163
165
160
167
164
144
150
162
161
178
142B
153
155
150
157
154
172
156
151
152
142A
148
146
132
122
Power Steering Unit (16)
16B
16A
106
102A
104
102B
102C
105
100
108
121

FIG. 7

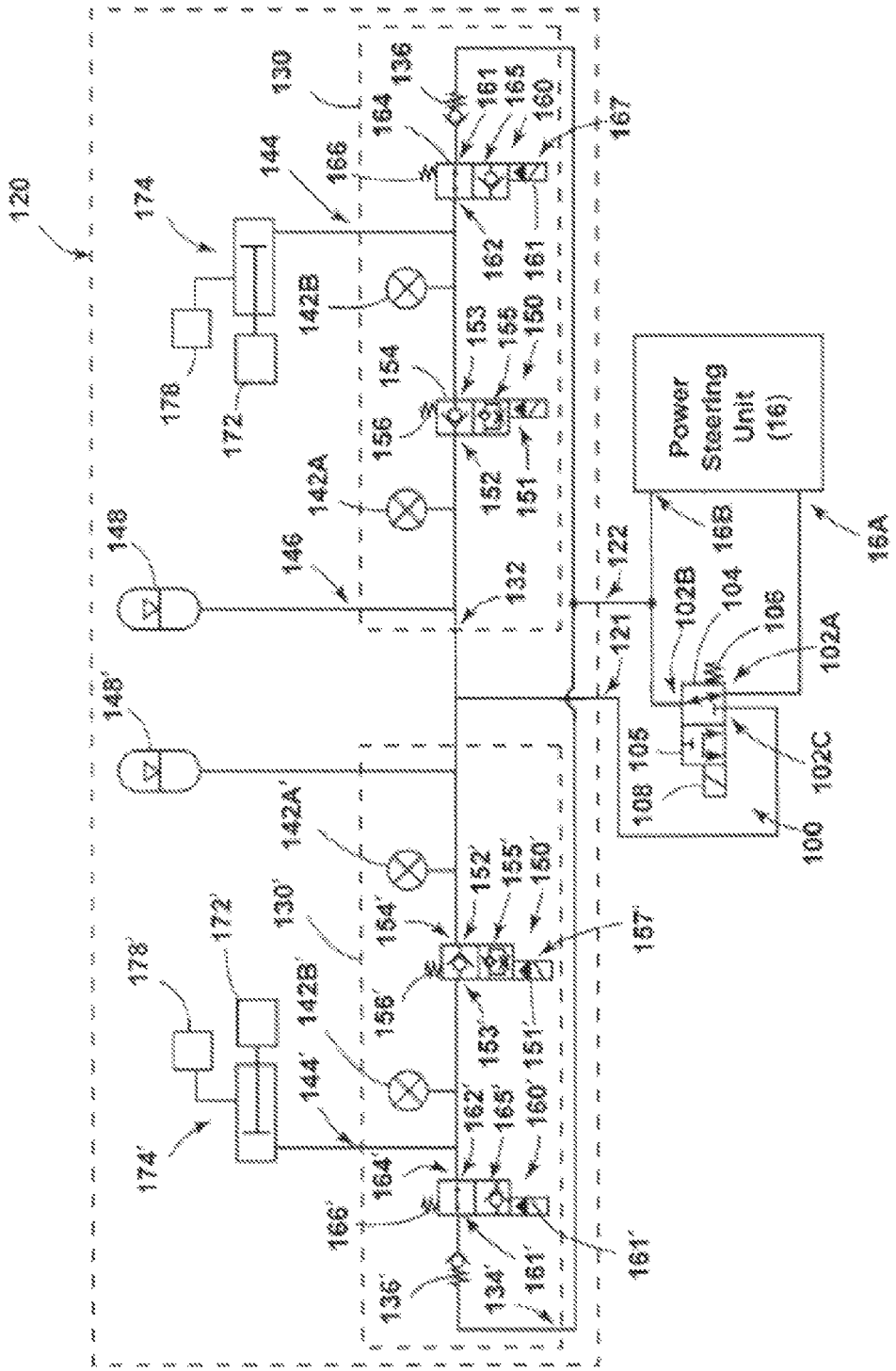

FIG. 8

HYDRAULIC POWER SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation of and claims the benefit of PCT Application No. PCT/US2014/027913, filed on Mar. 14, 2014, which claims the benefit of U.S. Provisional Application Ser. No. 61/798,893, filed Mar. 15, 2013, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present disclosure relates to vehicle hydraulic power systems, including hydraulically-actuated differentials.

BACKGROUND

Vehicles often include several hydraulically powered units—i.e., power steering units and differential units. Often, each hydraulically-powered unit includes its own source of fluid and its own pump. However, including such individual pumps and sources of fluid for each hydraulically-powered unit may undesirably increase the weight of the vehicle and reduce efficiency.

SUMMARY

A hydraulic actuation system in accordance with an embodiment of the present disclosure includes a differential unit having a hydraulically-actuated differential, a power steering unit, a hydraulic pump, a reservoir, a controller, an electronically-controlled flow control manifold, and a proportional pressure control solenoid valve. A flow control manifold may control fluid flow to the power steering unit and the differential. The manifold may include a manifold inlet connected to a pump; a first manifold outlet connected to a differential; a second manifold outlet connected to a reservoir; a third manifold outlet connected to a power steering unit; a two-way solenoid valve connected to a manifold inlet and controlled by a controller; a flow control valve connected to a two-way solenoid valve and a first manifold outlet; and a pressure differential sensing valve connected to a two-way solenoid valve, the manifold inlet, and the third manifold outlet. In an embodiment, a proportional pressure control solenoid valve may connect the first manifold outlet and the differential. In an embodiment, a controller may be configured to control fluid flow in the system to prioritize providing fluid flow to the power steering unit relative to providing fluid flow to the differential unit.

Additional disclosures are provided and illustrated in the following sections and associated Figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the disclosed subject matter will now be described, by way of example, with reference to the accompanying drawings, wherein:

FIG. **1** generally illustrates an embodiment of a hydraulic power system in accordance with teachings of this disclosure.

FIGS. **2-5** generally illustrate front, top, left, and back views of embodiments of an electronically-controlled flow control manifold in accordance with teachings of this disclosure.

FIG. **6** generally illustrates an embodiment of a differential unit in accordance with teachings of this disclosure.

FIG. **7** generally illustrates an embodiment of a hydraulic power system in accordance with teachings of this disclosure.

FIG. **8** generally illustrates an embodiment of a hydraulic power system in accordance with teachings of this disclosure.

DETAILED DESCRIPTION

Reference will now be made in detail with respect to embodiments of the present disclosure, examples of which are described herein and illustrated in the accompanying drawings. While concepts will be described in conjunction with embodiments, it will be understood that the invention is not intended to be limited to the specific disclosures associated with the embodiments. On the contrary, the invention is intended to cover alternatives, modifications and equivalents, which may be included within the spirit and scope of the invention as defined by the appended claims.

FIG. **1** generally illustrates a diagram view of an embodiment of a hydraulic power system **10**. System **10** may be configured to control pressurized fluid flow to and/or between both a power steering unit **16** and a differential unit **70**. For example, and without limitation, system **10** may be configured to prioritize fluid demands of power steering unit **16** over fluid demands of differential unit **70**.

In an embodiment, system **10** may include a pump **12**, a reservoir **14**, a relief valve **20**, an electronically-controlled flow control manifold **30**, a power steering unit **16**, a differential unit **70**, and/or an electronic control unit (ECU) **18**.

A pump **12** may, for example, comprise a hydraulic pump. Pump **12** may be unidirectional or bidirectional, and may provide fixed displacement and/or variable displacement. The pump **12** may be coupled to a pump driver **13**, which may comprise an electric motor and/or a vehicle engine. For example, and without limitation, pump **12** may be coupled with a serpentine belt of a vehicle **78**. Pump **12** may be connected to reservoir **14** and may be configured to provide fluid from reservoir **14** to electronically-controlled flow control manifold **30**. Pump **12** may be included in power steering unit **16**.

A reservoir **14** may be configured to at least temporarily store fluid, and may, without limitation, include a tank and/or sump. The reservoir **14** may be configured to provide a source of fluid for system **10**. Reservoir **14** may, additionally or alternatively, be configured to receive return fluid associated with system **10**.

System **10** may include at least one relief valve **20**. In an embodiment, relief valve **20** may be disposed or connected between pump **12** and electronically-controlled flow control manifold **30**. Relief valve **20** may include an inlet **21**, an outlet **22**, and/or a sensing port **23**. Relief valve inlet **21** may be connected to pump **12**, and relief valve outlet **22** may be connected to reservoir **14**. Relief valve may have a first position which may correspond to relief valve **20** preventing fluid flow from relief valve inlet **21** to relief valve outlet **22**. Relief valve **20** may include a second position, generally shown in phantom, which may correspond to relief valve **20** permitting fluid flow from relief valve inlet **21** to relief valve outlet **22**. In an embodiment, relief valve **20** may be configured to transition between its first and second positions according to a fluid pressure at relief valve inlet **21**. For example, and without limitation, relief valve **20** may be configured to transition from the first position to the second position if the fluid pressure at relief valve inlet **21** exceeds a set or threshold pressure. Moreover, relief valve **20** may include a biasing member **26** that may provide a force that, for example, can correspond to a set or threshold pressure.

As generally illustrated in FIGS. **1-4**, in an embodiment, system **10** may include an electronically-controlled flow control manifold **30**. Manifold **30** may include an inlet **31**, a first manifold outlet **32**A, a second manifold outlet **32**B, and/or a third manifold outlet **32**C. In an embodiment, manifold **30** may include a check valve **36**, a two-way solenoid control valve **40**, an adjustable flow control valve **50**, a pressure differential sensing valve **60**, and/or at least one fixed restriction **28**.

A manifold inlet **31** may be connected to pump **12** and/or relief valve **20**, two-way solenoid valve **40**, and/or sensing valve **60**. First outlet **32**A and second outlet **32**B may be connected to each other and/or connected to adjustable flow control valve **50**. Additionally or alternatively, first manifold outlet **32***a* may be connected to differential unit **70**, and/or second manifold outlet **32**B may be connected to reservoir **14**. Third manifold outlet **32**C may be connected to power steering unit **16** and/or sensing valve outlet **62**.

A two-way solenoid control valve **40**, which may be referred to as control valve **40**, may include an inlet **41**, an outlet **42**, a solenoid **45**, a first portion **43**, and/or a second portion **44**. Control valve inlet **41** may be connected to manifold inlet **31**, sensing valve inlet **61**, and/or sensing valve second sensing port **63**B. Control valve outlet **42** may be connected to adjustable flow control valve **50**. Control valve outlet **42** may be connected to adjustable flow control valve **50** via a fixed restriction **28**.

A control valve first portion **43** may correspond to control valve **40** preventing fluid flow from control valve inlet **41** to control valve outlet **42**. First portion **43** may, additionally or alternatively, correspond to control valve **40** permitting fluid flow from control valve outlet **42** to control valve inlet **41**. Control valve second portion **44** may permit relatively unrestricted fluid flow from control valve inlet **41** to control valve outlet **42**. Control valve second portion **44** may, additionally or alternatively, correspond to control valve **40** permitting restricted fluid flow from control valve outlet **42** to control valve inlet **41**.

A solenoid **45** may be configured to transition control valve **40** between a first position in which first portion **43** may be connected to inlet **41** and outlet **42**, and a second position in which second portion **44** may be connected to inlet **41** and outlet **42**. Solenoid **45** may be connected to ECU **18**, for example, via connector **47**. ECU **18** may be configured to cause control valve solenoid **45** to transition control valve **40** between its first and second positions. Control valve **40** may include a biasing member **46** that may bias control valve **40** toward its first position and/or its second position.

An adjustable flow control valve **50**, which may be referred to as flow control valve **50**, may include an inlet **51** and an outlet **52**. Flow control valve **50** may permit relatively unrestricted fluid flow in a direction from its outlet **52** to its inlet **51**. Flow control valve **50** may also permit and/or restrict fluid flow in a direction from its inlet **51** to its outlet **52**. The degree to which flow control valve **50** permits and/or restricts flow may be adjustable. Flow control valve **50** may be adjusted manually and/or automatically. Flow control valve may be connected to ECU **18**. For example, and without limitation, ECU **18** may be configured to adjust the degree of flow restriction provided by flow control valve **50**.

A manifold **30** may include a pressure differential sensing valve **60**, which may be referred to as sensing valve **60**. Sensing valve **60** may include an inlet **61**, an outlet **62**, a first sensing port **63**A, and/r a second sensing port **63**B. First sensing port **63**A may be connected to flow control valve outlet **52**, first manifold outlet **32**A, and/or second manifold outlet **32**B. First sensing port **63**A may be configured to receive pressurized fluid that may correspond to a fluid pressure of differential unit **70**. Second pressure sensing port **63**B may be connected to sensing valve inlet **61**, manifold inlet **31**, and/or control valve inlet **41**. Second pressure sensing port **63**B may be configured to provide fluid that may be pressurized at a pressure corresponding to a pressure at manifold inlet **41**.

A sensing valve **60** may include a first position that may correspond to sensing valve **60** preventing fluid flow in a direction from its inlet **61** to its outlet **62**. Sensing valve **60** may include a second position, shown in phantom, that may correspond to sensing valve **60** permitting fluid flow in a direction from its inlet **61** to its outlet **62**.

In an embodiment, sensing valve **60** may include a biasing member **66** that may be configured to bias sensing valve **60** toward its first position and/or its second position. Sensing valve biasing member **66** may be configured to provide a biasing force that may correspond to a desired pressure differential between first sensing port **63**A and second sensing port **63**B. For example, and without limitation, sensing valve biasing member **66** may comprise a spring configured to bias sensing valve **60** toward its first position. If a pressure at second sensing port **63**B is sufficiently high, the biasing force of biasing member **66** may be overcome and sensing valve **60** may transition sensing valve **60** from its first position toward its second position.

In an embodiment, manifold **30** may include one or more fixed restrictions **28**, **28**A. Fixed restrictions **28**, **28**A may comprise an orifice and/or a pre-set flow regulator. Fixed restrictions **28**, **28**A may limit the amount of fluid that can flow through them. For example, and without limitation, fixed restriction **28** may comprise an orifice and may be connected and/or disposed between two-way solenoid valve **40** and flow control valve **50**, and fixed restriction **28**A may comprise a pre-set flow regulator may be connected and/or disposed between flow control valve **50** and reservoir **14**.

System **10** may include a power steering unit **16**. Power steering unit **16** may be configured to be disposed in a vehicle. Power steering unit **16** may be configured to generate a force to cause a vehicle (e.g., vehicle **78**) to turn.

As generally illustrated in FIG. **6**, in an embodiment, system **10** may include a differential unit **70**. Differential unit **70** may include a first pressure sensor **71**A, a second pressure sensor **71**B, an accumulator **72**, a proportional pressure control valve **80**, and/or a hydraulically-actuated differential **90**. First pressure sensor **71**A and/or second pressure sensor **71**B may be configured to sense a fluid pressure. Pressure sensors **71**A, **71**B may include pressure transducers. First pressure sensor **71**A may be connected between accumulator **72** and proportional pressure control valve **80**, and/or may be configured to sense an accumulator pressure. Second pressure sensor **71**B may be connected between proportional pressure control valve **80** and hydraulically-actuated differential **90**, and/or may be configured to sense a clutch pressure of hydraulically-actuated differential **90**. First pressure sensor **71**A and/or second pressure sensor **71**B may be connected to and/or monitored by ECU **18**.

A differential unit **70** may include a proportional pressure control valve **80**, which may be referred to as proportional valve **80**. Proportional valve **80** may include a first port **81**A, a second port **81**B, a third port **81**C, a first portion **82**, a second portion **83**, a solenoid **85**, and/or a biasing member **86**. For example, and without limitation, first port **81**A may be connected to reservoir **14**, second port **81**B may be connected to accumulator **72** and/or manifold **30**, and third port **81**C may be connected to hydraulically-actuated differential **90**.

First portion **82** may correspond to proportional valve **80** permitting fluid flow between first port **81**A and third port **81**C. First portion **82** may also correspond to proportional valve **80** blocking second port **81**B. For example, and without limitation, first position **82** may be configured to permit fluid flow from hydraulically-actuated differential **90** to reservoir **14**.

Second portion **83** may correspond to proportional valve **80** permitting flow between second port **81**B and third port **81**C. Second portion **83** may also correspond to proportional valve **80** blocking first port **81**A. For example, and without limitation, second portion **83** may be configured to permit to fluid flow from manifold **30** and/or accumulator **72** to hydraulically-actuated differential **90**.

In an embodiment, proportional valve **80** may include a first position in which first portion **82** is connected to first, second, and third ports **81**A, **81**B, **81**C. Proportional valve may also include a second position in which second portion **83** is connected to first, second, and third ports **81**A, **81**B, **81**C.

In an embodiment, differential unit may include an accumulator **72**. Accumulator **72** may be connected between manifold **30** and proportional valve **80**. Accumulator **72** may be configured to receive and/or at least temporarily store pressurized fluid. Manifold **30** may be configured to provide pressurized fluid to accumulator **72**. For example, and without limitation, accumulator **72** may be configured to receive pressurized fluid if it is not desired to provide the pressurized fluid to proportional valve **80**, such as if proportional valve **80** is in its first position. Accumulator **72** may be configured to at least temporarily provide a source of fluid to system **10**. For example, and without limitation, accumulator **72** may provide pressurized fluid to proportional valve **80** if manifold **30** is not providing a desired amount of pressurized fluid. For example, and without limitation, manifold **30** may not provide a desired amount of pressurized fluid if proportional valve **80** is in its second position, but manifold **30** is directing most or all of the pressurized fluid from pump **12** to power steering unit **16**.

Differential unit **70** may include a hydraulically-actuated differential **90**. Hydraulically-actuated differential **90** may include at least one clutch pack **92**. Clutch pack **92** may comprise a multi-plate wet clutch pack. Differential unit **70** may include one or more actuators **94**, which may comprise a cylinder. Actuator **94** may be configured to actuate clutch pack **92**. Actuator **94** may be biased by a biasing member **96**. Proportional valve **80** may be configured to provide pressurized fluid to actuator **94**. Proportional valve **80** may be configured to provide a sufficient amount of pressurized fluid to overcome biasing member **96** and to actuate clutch pack **92**. As generally illustrated in FIG. **1**, differential unit **70** may be at least partially disposed in a transaxle case **76** of a vehicle **78** that may be a front-wheel drive automobile.

As generally illustrated in FIG. **7**, in an embodiment, system **10** may include a differential unit control valve **100** and a differential unit **120**. Differential unit control valve **100**, which may be referred to as control valve **100**, may be configured to at least partially control fluid flow between power steering unit **16** and differential unit **120**. Power steering unit may be configured to provide fluid to control valve **100**. ECU **18** may be configured control the amount of fluid power steering unit **16** provides to control valve **100**, which may include prioritizing the availability of pressurized fluid for power steering unit **16** relative to the availability of pressurized fluid for control valve **100**.

Control valve **100** may include a first control valve port **102**A that may be connected to power steering unit outlet **16**A, a second control valve port **102**B that may be connected to differential unit outlet **122** and/or power steering unit inlet **16**B, and a third control valve port **102**C that may be connected to differential unit inlet **121**. Control valve **100** may include a first portion **104** and a second portion **105**. First portion **104** may correspond to control valve **100** permitting fluid flow between its second and third ports **102**B, **102**C, which may permit fluid flow between differential unit outlet **122** and power steering unit inlet **16**A. Second portion **105** may correspond to control valve **100** permitting fluid flow between its first and third ports **101**A, **101**B, which may permit fluid flow between power steering unit outlet **16**B and differential unit inlet **121**.

In an embodiment, control valve **100** may include a first position in which first portion **104** is connected to first, second, and third ports **102**A, **102**B, **102**C. Control valve **100** may also include a second position in which second portion **105** is connected to first, second, and third ports **102**A, **102**B, **102**C. Control valve **100** may include a solenoid **108** that may be configured to transition control valve **100** between its first and second positions. Control valve solenoid **108** may be connected to and/or controlled by ECU **18**. Control valve **100** may include a biasing member **106** that may bias control valve **100** toward first position **104** and/or second position **105**.

Differential unit **120** may include a control manifold **130** and a hydraulically-actuated differential **150**. Control manifold **130** may be configured to at least partially control fluid flow to hydraulically-actuated differential **150**. Control manifold **130** may include an inlet **132**, an outlet **134**, a check valve **136**, a first control valve **150**, a second control valve **160**, a first pressure sensor **142**A, a second pressure sensor **142**B, an actuator port **144**, and/or an accumulator port **148**. Check valve **136** may permit fluid flow in a direction out of differential unit **120** through outlet **122** and may prevent fluid flow in a direction into differential unit **120** through control manifold outlet **122**.

Accumulator port **146** may be connected to control manifold inlet **132** and may be configured to be connected to an accumulator **148**. Accumulator **148** may be configured to receive and/or at least temporarily store pressurized fluid. Control valve **100** may be configured to provide pressurized fluid to accumulator **148**. For example, and without limitation, accumulator **148** may be configured to receive pressurized fluid if it is not desired to provide the pressurized fluid to first control valve **150**. Accumulator **148** may also be configured to at least temporarily provide a source of fluid to system **10**. For example, and without limitation, accumulator **148** may provide pressurized fluid to first control valve **150** if control valve **100** is not providing a desired amount of pressurized fluid. For example, and without limitation, control valve **100** may not provide a desired amount of pressurized fluid if control valve **100** directing most or all of the pressurized fluid provided by power steering unit **16** back to power steering unit **16**.

First control valve **150** may comprise a two-way solenoid control valve. First control valve **150** may include a solenoid **151**, an inlet **152**, an outlet **153**, a first portion **154**, and/or a second portion **155**. First control valve inlet **152** may be connected to differential unit inlet **121**, first pressure sensor **142**A, and/or accumulator **148**. First control valve outlet **153** may be connected to actuator port **144**, second pressure sensor **142**B, and/or second control valve **160**.

First portion **154** may correspond to first control valve **150** permitting fluid flow in a direction from its inlet **152** to its outlet **153**. First portion **154** may also correspond to first control valve **150** preventing fluid flow in a direction from its

outlet **153** to its inlet **152**. Second portion **155** may correspond to first control valve **150** permitting fluid flow in a direction from its outlet **153** to its inlet **152**. Second portion **155** may also correspond to first control valve **150** allowing restricted fluid flow from its inlet **152** to its outlet **153**. First control valve **150** may include a first position in which its first portion **154** is connected to inlet **152** and outlet **153**. First control valve **150** may also include a second position in which its second portion **155** is connected to inlet **152** and outlet **153**.

Solenoid **151** may be configured to transition first control valve **150** between its first and second position. Solenoid **151** may be connected to ECU **18**. ECU **18** may be configured to cause solenoid **151** to transition first control valve **150** between its first and second positions. First control valve **150** may include a biasing member **156** that may bias first control valve **150** toward its first position and/or its second position. First control valve **150** may, additionally or alternatively, be configured to be pilot operated and may include a pilot port **157**.

Second control valve **160** may comprise a two-way solenoid control valve and may include a solenoid **161**, an inlet **162**, an outlet **163**, a first portion **164**, and/or a second portion **165**. Second control valve inlet **162** may be connected to first control valve outlet **163**, second pressure sensor **142**B, and/or actuator port **144**. Second control valve outlet **163** may be connected to control valve second port **102**B which may be via check valve **136**.

First portion **164** may correspond to second control valve **160** permitting fluid flow between its inlet **162** and its outlet **163**. Second portion **165** may correspond to second control valve **160** permitting fluid flow in a direction from its inlet to its outlet. Second control valve second portion **165** may also correspond to second control valve **160** preventing fluid flow in a direction from its outlet **163** to its inlet **162**. Second control valve **160** may include a first position in which its first portion **164** is connected to inlet **162** and outlet **163**. Second control valve **160** may also include a second position in which its second portion **165** is connected to inlet **162** and outlet **163**.

Solenoid **161** may be configured to transition second control valve **160** between its first and second positions. Solenoid **161** may be connected to ECU **18**. ECU **18** may be configured to cause second control valve solenoid **161** to transition second control valve **160** between its first and second positions. Second control valve **160** may include a biasing member **166** that may bias second control valve **160** toward its first position **164** and/or its second position **165**. Second control valve **160** may, additionally or alternatively, be configured to be pilot operated and may include a pilot port **167**.

Differential unit **120** may include a first pressure sensor **142**A and a second pressure sensor **142**B. Pressure sensors **142**A, **142**B may be configured to sense a fluid pressure of system **10** and may include pressure transducers. First pressure sensor **142**A may be connected between accumulator **148** and first control valve **150** and may be configured to sense an accumulator pressure. Second pressure sensor **142**B may be connected between first control valve **150** and hydraulically-actuated differential **170** and may be configured to sense a clutch pressure of hydraulically-actuated differential **170**.

Hydraulically-actuated differential **170** may include at least one clutch pack **172**. Clutch pack **172** may comprise a multi-plate wet clutch pack. Hydraulically-actuated differential **170** may include at least one actuator **174**, which may be connected to actuator port **144**. Actuator **174** may comprise a cylinder and/or may be configured to actuate clutch pack **172**. Actuator **174** may be biased by a biasing member **176** and/or may be connected to a bleed valve **178**. Control manifold **130** may be configured to provide pressurized fluid to actuator **174**, which may actuate clutch pack **172**. For example, and without limitation, control manifold **130** may be configured to provide an amount of sufficiently pressurized fluid to actuator **174** to overcome biasing member **176** and actuate clutch pack **172**.

In an embodiment, hydraulically-actuated differential **170** may comprise more than one actuator, such as actuators **174**, **174'**. Control manifold **130** may be configured to control fluid flow to both actuators **174**, **174'** and/or, as generally illustrated in FIG. **8**, system **10** may include more than one manifold, such as control manifold **130** and second control manifold **130'**. Second control manifold **130'** may be configured substantially the same as first control manifold **130**, but second control manifold **130'** may be configured to control fluid flow to actuator **174'**. For example, and without limitation, second control manifold **130'** may include an inlet **132'**, an outlet **134'**, an accumulator port **146'**, an actuator port **144'**, a first control valve **150'**, a second control valve **160'**, a check valve **136'**, accumulator **148'**, first pressure sensor **142**A', and/or second pressure sensor **142**B'. Second control manifold **130'** may be connected to control manifold **130**.

In an embodiment, ECU **18** may comprise a programmable microprocessor and/or microcontroller, and/or may comprise an application specific integrated circuit (ASIC), for example. ECU may include a central processing unit (CPU), memory, and/or an input/output (I/O) interface. ECU **18** may be configured to perform various functions, such as those described in greater detail herein, with appropriate programming instructions and/or code embodied in software, hardware, and/or other medium.

In an embodiment, ECU **18** may be configured to at least partially control the flow of fluid within system **10**. For example, and without limitation, ECU **18** may control the flow of fluid between pump **12**, power steering unit **16**, manifold **30**, and differential unit **70**. ECU **18** may, without limitation, be connected to manifold **30**, power steering unit **16**, and/or differential unit **70**. ECU **18** may monitor pressure sensor **71**A to determine an accumulator pressure of accumulator **72**. If the accumulator pressure is below a minimum threshold, such as, without limitation, about 300 psi, ECU **18** may energize solenoid **45** to cause control valve **40** toward shift to its second position. If control valve **40** shifts toward its second position, pressurized fluid from pump **12** may be permitted to flow through fixed restriction **28**, flow control valve **50**, manifold first outlet **32***a*, and to differential unit **70**. The pressurized fluid may flow to accumulator **72** until a maximum accumulator pressure is reached, such as, without limitation, about 800 psi. ECU **18** may monitor pressure sensor **71**A to determine that the maximum accumulator pressure has been reached and may de-energize solenoid **45** to cause control valve **40** to shift toward its first position.

In an embodiment, ECU **18** may be configured to prioritize fluid flow to power steering unit **16** and ensure that power steering unit **16** receives sufficient pressurized fluid from pump **12**. Providing sufficient pressurized fluid flow to power steering unit **16** may be desirable to maintain proper functioning of power steering unit **16**, which may ensure that a driver of a vehicle **78** is able to drive safely. For example, and without limitation, if control valve **40** is in its first position, fluid is not permitted to flow from pump **12** to differential unit **70** and power steering unit may receive all available fluid from pump **12**. If transitioned toward its second position, control valve **40** may allow fluid from pump **12** to be directed to differential unit **70**, but the flow may be restricted by fixed

orifice **28** and/or flow control valve **50**. The flow restriction provided by fixed orifice **28** may limit fluid flow to differential unit **70** to a maximum flow rate. Flow control valve **50** may be configured to further increase the amount of flow restriction between pump **12** and differential unit **70**, which may include adjustably limiting fluid flow to a rate below the maximum flow rate. Such flow restrictions may ensure that power steering unit **16** receives sufficient fluid even if control valve **40** is in its second position. Additionally or alternatively, ECU **18** may be configured to determine if power steering unit **16** requires additional fluid and ECU **18** may be configured to energize solenoid **45** to transition control **40** to its first position and prevent fluid flow to differential unit **70**.

In an embodiment, ECU **18** may, additionally or alternatively, be connected to differential unit **70**. ECU may be connected to first pressure sensor **71**A, second pressure sensor **71**B, and/or proportional pressure control valve **80**. ECU **18** may be configured to energize and/or de-energize solenoid **85**, which may cause proportional valve **80** to transition between its first and second positions. For example, and without limitation, if it is desirable to provide fluid to hydraulically-actuated differential **70**, ECU **18** may be configured to energize solenoid **85**, which may cause proportional valve **80** to transition toward its second position.

In an embodiment, ECU may be connected to first control manifold **130**, second control manifold **130'**, control valve **100**, first pressure sensors **142**A, **142**A', and/or second pressure sensors **142**B, **142**B'. ECU **18** may be configured to independently and/or collectively energize and/or de-energize one or more of solenoids **108**, **151**, **151'**, **161**, **161'**, which may, respectively, cause control valve **100**, first control valves **150**, **150'**, and/or second control valves **160**, **160'** to transition between their respective first and second positions.

It will be appreciated that the above teachings are merely exemplary in nature and is not intended to limit the present teachings, their application or uses. While specific examples have been described in the specification and illustrated in the drawings, it will be understood by those of ordinary skill in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present teachings as defined in the claims. For example, and without limitation, it should be understood references to valves having first and/or second positions are not limited to only having two positions and are also not limited to being in only one position or another. On the contrary, any of the disclosed valves may be configured to be continuous variable between any number of positions the valve may have, which may allow a valve to provide continuously variable openings and/or ports. Moreover, references to valves have specific ports are not so limited. Instead, valves may have any number of ports. Additionally, references to pressure sensor (e.g., pressure sensor **71**A and/or **71**B) may include pressure transducers and may be connected to and/or monitored by ECU **18**.

Furthermore, the mixing and matching of features, elements and/or functions between various examples is expressly contemplated herein so that one of ordinary skill in the art would appreciate from this disclosure that features, elements and/or functions of one example may be incorporated into another example as appropriate, unless described otherwise, above. Moreover, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the essential scope thereof. Therefore, it is intended that the present teachings not be limited to the particular examples illustrated by the drawings and described in the specification as the best mode presently contemplated for carrying out the teachings of the present disclosure, but that the scope of the present disclosure will include any embodiments falling within the foregoing description and the appended claims.

What is claimed:

1. A hydraulic actuation system comprising:
- a differential unit including a hydraulically-actuated differential;
- a power steering unit;
- a hydraulic pump;
- a reservoir;
- a controller;
- an electronically-controlled flow control manifold configured to control fluid flow to the power steering unit and the hydraulically-actuated differential, the manifold including
  - a manifold inlet connected to the pump,
  - a first manifold outlet connected to the hydraulically-actuated differential,
  - a second manifold outlet connected to the reservoir,
  - a third manifold outlet connected to the power steering unit,
  - a two-way solenoid valve connected to the manifold inlet and controlled by the controller,
  - a flow control valve connected to the two-way solenoid valve and the first manifold outlet, and
  - a pressure differential sensing valve connected to the two-way solenoid valve, the manifold inlet, and the third manifold outlet; and,
- a proportional pressure control solenoid valve connected to the first manifold outlet and the hydraulically-actuated differential.

2. The actuation system of claim **1**, wherein the pressure differential sensing valve and the flow control valve are configured to limit fluid flow to the differential unit to a set or predetermined maximum flow rate.

3. The actuation system of claim **1**, wherein an outlet of the flow control valve is connected to the first manifold outlet, the second manifold outlet, and the pressure differential sensing valve.

4. The actuation system of claim **1**, including an accumulator connected between the first manifold outlet and the proportional pressure control valve.

5. The actuation system of claim **4**, including an accumulator pressure sensor connected between the accumulator and the proportional pressure control valve.

6. The actuation system of claim **5**, wherein the accumulator pressure sensor is connected to the controller.

7. The actuation system of claim **1**, including a clutch pressure sensor connected between the proportional pressure control valve and the hydraulically-actuated differential.

8. The actuation system of claim **7**, wherein the clutch pressure sensor is connected to the controller.

9. The actuation system of claim **1**, wherein the proportional pressure control valve is controlled by the controller.

10. The actuation system of claim **1**, wherein the proportional pressure control valve is a three-way normally closed valve.

11. The actuation system of claim **1**, wherein the hydraulically-actuated differential includes a multi-plate wet clutch pack.

12. The actuation system of claim **1**, wherein the hydraulically-actuated differential is at least partially disposed in a transaxle case.

13. The actuation system of claim **1**, wherein the proportional pressure control valve includes a first position, a second position, a first inlet, a second inlet, and an outlet.

14. The actuation system of claim 13, wherein the first position corresponds to the first inlet being connected to the outlet, and wherein the second position corresponds to the second inlet being connected to the outlet.

15. The actuation system of claim 1, wherein the two-way solenoid valve includes a first position, a second position, an inlet and an outlet.

16. The actuation system of claim 15, wherein the first position corresponds to fluid flow being permitted to flow from the inlet to the outlet, and wherein the second position corresponds to fluid flow being permitted to flow freely from the outlet to the inlet, and being at least partially restricted from flowing from the inlet to the outlet.

17. The actuation system of claim 1, wherein the flow control valve is configured to adjustably control fluid flow from an outlet of the two-way solenoid valve and freely permit fluid flow to the outlet of the two-way solenoid valve.

18. An automobile, comprising:

a hydraulic actuation system comprising:

a differential unit including a hydraulically-actuated differential;

a hydraulically-actuated power steering unit in fluid communication with the differential unit;

a hydraulic pump;

a hydraulic fluid reservoir;

a reservoir;

a controller; and

an electronically-controlled flow control manifold configured to control fluid flow to the power steering unit and the hydraulically-actuated differential, and

a proportional pressure control solenoid valve connected to the electronically-controlled flow control manifold and the hydraulically-actuated differential.

19. The automobile of claim 18, wherein the electronically-controlled flow control manifold includes

a manifold inlet connected to the pump;

a first manifold outlet connected to the hydraulically-actuated differential;

a second manifold outlet connected to the reservoir;

a third manifold outlet connected to the power steering unit;

a two-way solenoid valve connected to the manifold inlet and controlled by the controller;

a flow control valve connected to the two-way solenoid valve and the first manifold outlet; and

a pressure differential sensing valve connected to the two-way solenoid valve, the manifold inlet, and the third manifold outlet.

20. The automobile of claim 18, wherein the automobile is front-wheel drive and the differential unit is at least partially disposed in a transaxle case.

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